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Present situation in the production of artificial seedlings of *Strongylocentrotus intermedius* (Parts 1 and 2)

K. Tajima

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EZOBAFUNUNI JINKO SHUBYO SEISAN NO GENJO (SONO 1), (SONO 2)
(PRESENT SITUATION IN THE PRODUCTION OF ARTIFICIAL SEEDLINGS OF *Strongylocentrotus intermedius*, Parts 1 and 2)

Kenichiro TAJIMA

Hoku. Sui. Shi. Dayori (Hokkaido Fish. Exp. Stn. Newsletters 3-4), 1988. pp. 1-13

Part 1

1. Introduction

Research on the production of artificial seedlings of echinoids in Japan started at the end of the Showa 30's (1955-1964) at the Yamaguchi Prefectural Open Sea Fisheries Experimental Station for Bafununi (*Hemicentrotus pulcherrimus*) and Murasakiuni (*Heliocidaris crassispina*) and have progressed to those for Kitamurasakiuni (*Strongylocentrotus nudus*) at the Fukushima Prefectural Fisheries Experimental Station from the middle of the Showa 40's (1965-1974) and for Akauni (*Pseudocentrotus depressus*) at the Saga Prefectural Fisheries Experimental Station. In the Showa 50's (1975-1984), technological development in mass production progressed and the production of seedlings has been undertaken on a commercial scale. In some recent years, the yearly production of seedlings have risen to the millions. In Iwate Prefecture, a facility which can produce 5 million seedlings of *Strongylocentrotus intermedius* of 15 mm was constructed.

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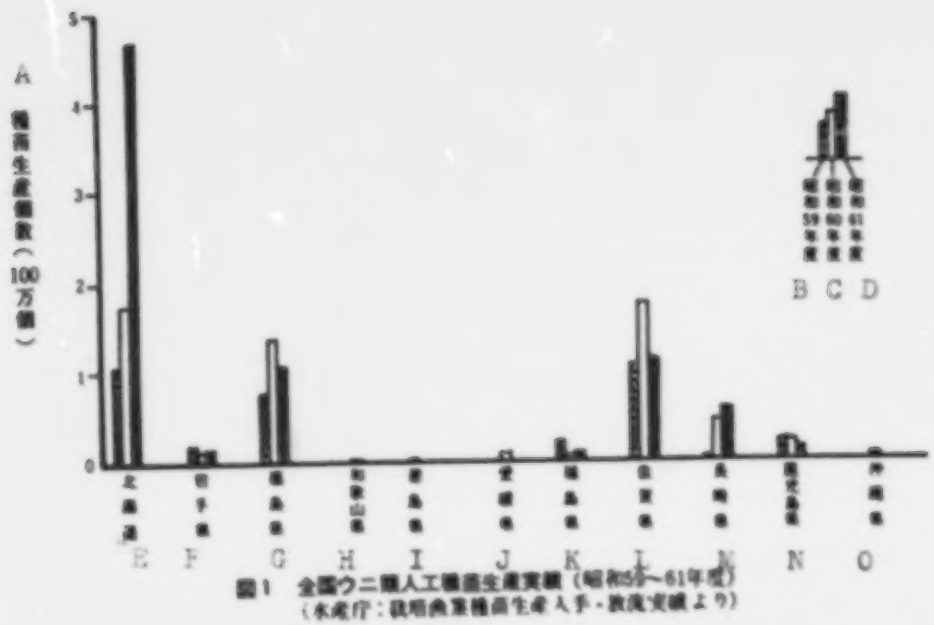

図1 全国ウニ類人工種苗生産実績（昭和59～61年度）
（水産庁：栽培漁業種苗生産入手・放流実績より）

Fig. 1 Production results of the artificial seedlings of echinoids in Japan (1984-1986) (Data from the Fisheries Agency: Acquisition and release results in the seedling production in the cultivation fisheries)

A. Number of seedlings produced (Million), B. 1984, C. 1985, D. 1986, E. Hokkaido, F. Iwate Prefecture, G. Fukushima Prefecture, H. Wakayama Prefecture, I. Tokushima Prefecture, J. Ehime Prefecture, K. Fukushima Prefecture, L. Saga Prefecture, M. Nagasaki Prefecture, N. Kagoshima Prefecture, O. Okinawa Prefecture

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It has been reported that the supply of seedlings will begin in 1988. Fig. 1 shows the production results of seedlings in major prefectures from 1984 to 1986.

In Hokkaido, at the end of the Showa 40's (1965-1974), basic research was carried out on the production of artificial seedlings of *Strongylocentrotus intermedius* with the Akkeshi Marine Laboratory of

Hokkaido University as the central facility. Experiments on the production of seedlings have been undertaken at the Kita Shiribeshi Propagation Association, the Hokkaido Federation of the Fishermen's Union, the Minamikayabe-cho, the Kutsukata and the Soya Fisheries Cooperative Associations. However, there have been many technological problems, such as the large fluctuation in the amount of seedlings produced.

Considering the current situation based on the results of the basic research on the production of artificial seedlings of sea urchins, technological developmental experiments at the Culture Fishery Center on the mass production of seedlings of *Strongylocentrotus intermedius* have been carried out between 1982 and 1984 and the technology has been advanced. Furthermore, from 1986, with the cooperation of the Hokkaido Culture Fisheries Promotion Corporation (Shikabe Branch), the Center has been carrying out experiments on the commercialization of production of sea urchin seedlings. The technology for low cost, reliable mass production of sea urchin seedlings has been developed. p. 2

The results have been as follows: 700,000 sea urchin seedlings of 5-15mm in the spring of 1986 (juvenile sea urchins born in the autumn of the previous year) and more than 1 million in the spring of 1987 (as above) have been produced. As a result, the production of artificial seedlings of sea urchins has been commercialized since the autumn of 1987 at the Shikabe Branch of the Corporation.

The process of production of artificial seedlings of sea urchins has been established largely by undertaking experiments in the technology for mass production of seedlings and experiments on the

commercialization of seedling production. The process can be divided for the most part as follows:

1. securing of parent sea urchins,
2. rearing of free-floating pluteus larvae,
3. rearing of juvenile sea urchins in the early stages,

and 4. rearing of juvenile sea urchins in the late stages.

It is important also to secure the feed appropriate to each stage of growth. For the free-floating pluteus larval stage, the cultivation of *Chaetoceros gracilis*, a species of diatoms, and for the settling to the early juvenile stage, that of *Ulvella lens*, a species of green algae, are carried out. For the late juvenile stage, it is necessary to secure Konbu (kelp, *Laminaria*), Anaaosa (*Ulva pertusa*) and Oitadori.*

The current stages of technological development at the Culture Fishery Center is described below for this process. The following points are discussed: in (1), "1. securing of parent sea urchins" and "2. rearing of free-floating pluteus larvae" ; in (2), "3. rearing of juvenile sea urchins in the early stages"; and "4. rearing of juvenile sea urchins in the late stages". Some details are different from the content of The Production Manual of Artificial Seedlings of *Strongylocentrotus intermedius* published by the Culture Fishery Center in 1985. This is due to technological improvements in the commercialization experiments in the later stages. The "revised edition" is going to be published shortly and readers are advised to refer to it for detailed information.

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* translator's note : as transliterated; species uncertain; same for * on p. 23 of present translation

2. Securing of parent sea urchins

2-1 Spawning period of *Strongylocentrotus intermedius*

The spawning period of *Strongylocentrotus intermedius* in the sea around Hokkaido can be divided into two categories: the Japan Sea type and the Sea of Okhotsk and Pacific Ocean type. The sea urchins of the Japan Sea type spawn mainly in the autumn. The sea urchins of the Sea of Okhotsk and Pacific Ocean type spawn from late spring to autumn. It is called a "dribbling spawning". It has been confirmed that there are two spawning periods, spring and autumn, for sea urchins of the Sea of Okhotsk and Pacific Ocean type in Funka-Wan and its vicinity.

2-2 Rearing of parent sea urchins

The spawning period of natural *Strongylocentrotus intermedius* in Hokkaido is from the end of April to the beginning of November, as noted above. In securing parent sea urchins in the natural state, it sometimes happens that the collection of parent sea urchins for the purpose of obtaining eggs leaves something to be desired because of problems in quality and timing. Therefore it is necessary to cultivate parent sea urchins beforehand. It is also necessary to control the maturity of parent sea urchins in order to obtain superior mature eggs in addition to those available from a natural spawning period. Experiments on this aspect have been conducted since 1982 at the Culture Fishery Center. As a result, for parent sea urchins produced at Shikabe-cho, it has become possible to obtain mature eggs from the end of February to the middle of March, two months earlier than the

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time at which eggs can be obtained naturally. For parent sea urchins collected from the Japan Sea, some natural eggs could be obtained in July. In both cases mature eggs could be obtained two to three months after cultivation began. In the case of parent sea urchins produced at Shikabe-cho, cultivation began from December of the previous year. They were reared at temperatures between 10-15°C. It is necessary to secure for food about 10 g of Konbu (kelp) per day per individual. When they are reared at natural water temperature, eggs can be collected at about the same time as for natural sea urchins or at slightly earlier times.

3. Rearing of free-floating pluteus larvae and settling

3-1 Culture of feed for free-floating echinopluteus larvae

As the feed for free-floating echinopluteus larvae, unicellular species which belong to *Chaetoceros* are used commonly in Japan. However, some cases are known in other countries in which flagellates were used in the rearing of echinopluteus larvae. At the Culture Fishery Center, *Heterosigma akashiwo*, a species of flagellates, was used from 1982 to 1984 in an experiment on technological development of mass production of seedlings. The growth of free-floating echinopluteus larvae was good, but the survival rate was low. There was also a drainage problem since the species causes red-tide. *Chaetoceros* was also used in an experiment at the same time and proved able to produce the same growth rate as *Heterosigma*, so only *Chaetoceros* has been used since 1985.

Table 1. Rearing conditions for free-floating pluteus larvae of *Strongylocentrotus intermedius*

表1 エゾバフンウニ浮遊幼生の飼育条件

	A 浮遊幼生の発育段階	B 日数（日目）	C 飼育水1mℓ中の給餌量	D 濾過筒ネット地の目合い	E 照明	F 飼育水温（℃）	G 24時間当りの給水量（ℓ/0.5t）
a	四腕期	5（0～4）	1万細胞 cells	NXX 13	1連続	18.0～17.5	300
b	六腕期	3（5～7）	2万		2日中のみ	17.5～17.0	
c	八腕前期	3（8～10）	3万	NXX 9		17.0～16.5	600
d	八腕中期	3（11～13）	4万			16.5～16.0	
e	八腕後期	3（14～16）	5万			16.0～15.5	
f	変態期	4（17～20）	6万			15.5～15.0	

A. Growth stages of free-floating pluteus larvae, B. Number of days (duration in days), C. Amount of feed given per mL of of rearing water (10,000 to 60,000 cells), D. Mesh size of the net in the filtration tube, E. Lighting: 1. Continuous, 2. Daytime only; F. Rearing temperature (°C), G. Amount of water supplied per 24 hours; A: a. 4-arm stage, b. 6-arm stage, c. early 8-arm stage, d. intermediate 8-arm stage, e. late 8-arm stage, f. metamorphosis stage

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As shown in Table 1, the amount of feed differs with the growth stage. In order to ensure the necessary amount of feed, about one month of culture time is needed prior to the commencement of rearing the larvae including a preliminary culture period. Preliminary culture is carried out using a test tube, a 100 cc and a 300 cc conical flask without aeration. The production culture is carried out using 1-3 L flat-bottom flasks with aeration. However, the lesser the volume, the higher the culture density. Therefore, at the 4-arm stage, *Chaetoceros*

which has been propagated to the highest density in a 1 L flat-bottom flask is used. At the 6-arm and early 8-arm stages, *Chaetoceros* which has been propagated to the highest density in a 2 L flat-bottom flask is used. After the intermediate 8-arm stage, as a large amount of feed is required, *Chaetoceros* which has been cultured to large quantities in a 3 L flat-bottom flask is fed according to the requirements given in Table 1. For the culture of feed required at the stages after the intermediate 8-arm stage, heat-resisting poly bags and 30 L water tanks have been tried.

3-2 Collection of eggs and sperms

Firstly, the mouth part of a parent sea urchin is extracted using a pair of curved tweezers. Secondly, the inside of the coelom is washed with finely filtered sea water (a filter under 1 micron is used). Thirdly, the coelom is placed over a styrene tubal bottle filled with finely filtered sea water so that the gonadal orifice is immersed sufficiently. Five filamentous eggs or sperms can come out of the gonadal orifice of a mature individual. In the case of a female sea urchin, eggs are released, but in the case of a male, the gonad is extracted from the test after the release of sperms is confirmed.

3-3 Insemination

The temperature of a larvae rearing chamber is adjusted to be 18°C. Five L of finely filtered sea water is placed in a 10 L round styrene water tank (30 cm in diameter and 15 cm in depth) for insemination. The eggs in the styrene tubal bottle are transferred to this tank until the number of eggs reaches approximately 1 million as estimated by eye (the bottom of the tank becomes slightly coloured).

The sperms from several individuals are mixed and made into the original seminal fluid. One cc of the fluid is extracted with a syringe and put into 50 cc of finely filtered sea water to make up the seminal fluid. From this, 1 cc is injected into the round water tank containing the eggs. Then the contents are mixed gently with a circular motion and the insemination takes place. The original seminal fluid has been diluted by 1/250,000. If there are many sperms, many abnormal eggs result, and if there are few sperms, the rate of fertilization decreases. If the seminal fluid is allowed to stand for an extended period, fertility decreases. Therefore, the injection of the seminal fluid into the 10 L round water tank should be accomplished within 30 seconds to complete the insemination. After the insemination the sea water is stirred again with a circular motion and foreign substances such as fragments of spines are removed with a syringe. The contents are allowed to stand for 30 minutes. After confirmation that the eggs are precipitated, the supernatant sea water is discarded. Then the eggs are washed by adding fresh finely filtered sea water. The eggs are washed 5 times and sea water which contains sperm is replaced. After the eggs have been washed 5 times, a sufficient amount of finely filtered sea water is added and the mixture is allowed to stand until the next day.

About 20 hours after fertilization, larvae are hatched from the eggs and begin swimming actively. At this point, the larvae are removed from the 10 L round water tank to a 20 L square water tank. A desirable density in the square water tank is between 20 and 30 individuals/cc. The density is adjusted by sampling 3 times using a 5 cc

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syringe. When a sampling shows too many individuals, a portion of the larvae are dispersed or discarded. In order to prevent larvae from gathering at the surface of the water, a light in the rearing chamber is kept on and slight aeration is provided. About 48 hours after fertilization, the size and skeletal condition of the larvae are observed and the larvae to be reared are selected. The criteria are the following: the average body length should be greater than 250 microns; the larva should be in the shape of a pyramid; the skeleton should have no abnormal protuberance and there should be no crossing nor opening at the aboral.

3-4 Rearing of free-floating pluteus larvae

About 48 hours after fertilization, the larvae are put into a rearing tank (0 day of rearing). The equipment necessary for rearing larvae is shown in Fig. 2. For 5 rearing tanks 1 water exchange tank is used. Sea water which has been filtered through a 1 micron cartridge filter is fed into the water exchange tank. The water temperature is regulated by a thermoheater so that it lies between 15-18°C. However, when the natural sea water is higher than 18°C, it is cooled to lower than 15°C by a cooler and then heated again to the set temperature. The sea water with this adjusted temperature is then distributed to the rearing tanks. A rearing tank for free-floating pluteus larvae is shown in Fig. 3. The water outlet is placed at the bottom part of the rearing tank. The overflow is drained through a drainage filter pipe with a plankton net (nxx13 or nxx9 mesh). White fluorescent lamps are used for lighting which is set to about 900 lux on the surface of the rearing water. The light from outdoors is shielded.

Aeration is provided near the water surface and at the bottom. It is introduced gently at the bottom but more forcefully near the surface so that ripples are produced. The rearing conditions for larvae are given in Table 1.

p. 6

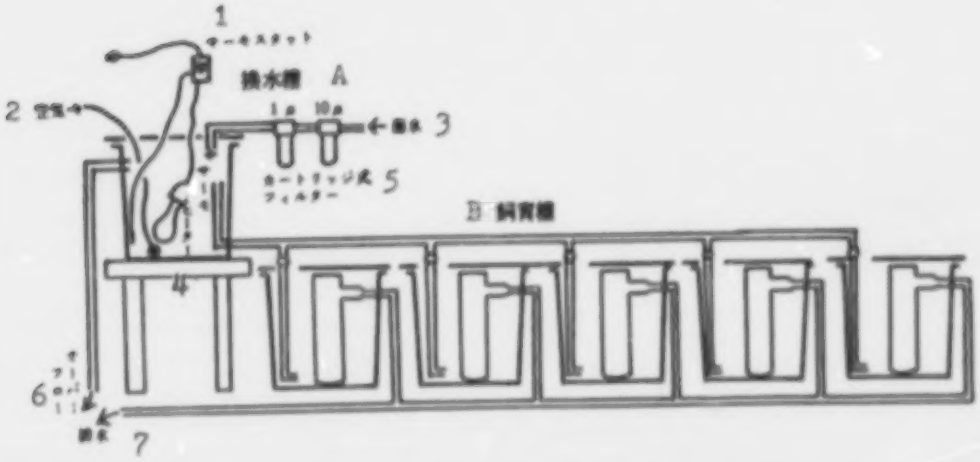

図1 浮遊幼生飼育装置（断面図）

Fig.2 Equipment for rearing free-floating pluteus larvae (cross section)

A. Water exchange tank, B. Rearing tank: 1. Thermostat, 2. Air, 3. Sea water, 4. Thermoheater, 5. Cartridge filter, 6. Overflow, 7. Drainage.

3-5 Metamorphosis of larvae and settlement

After 17-18 days from the commencement of the rearing process, the larvae reach the metamorphosis stage. The echinus rudiment in the larval cavity develops and becomes larger than the diameter of the stomach. Later a part of the body ruptures so that the primary tube-feet can emerge and the larvae can settle. At this time, settled juvenile

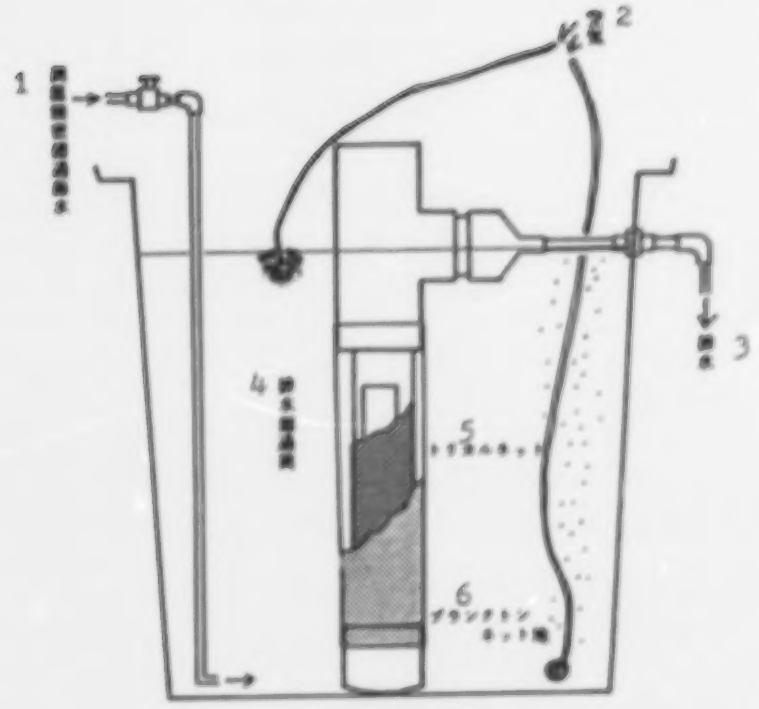

図3 浮遊幼生飼育槽 (断面図)

Fig. 3. Rearing tank for free-floating pluteus larvae (cross-section)

1. Temperature-adjusted finely filtered sea water, 2. Air, 3. Drainage, 4. Drainage filter pipe, 5. Trical** net, 6. Plankton net.

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sea urchins can be observed on the walls of the larval rearing tanks. About 1 or 2 days later, more settled juvenile larvae are so observed. At this time the larvae at the metamorphosis stage are transferred to a settlement tank with the rearing water. According to the experimental results so far, the settlement rate is between 40-60 %. The desirable water temperature for settlement is within the range 12-18°C (±3°C

** translator's note : a guess; meaning uncertain; could be a brand name; same hereafter for ** on pp. 22, 24 of present translation

Table 2. Results of transportation experiments for the larvae of *Strongylocentrotus intermedius* at the metamorphosis stage

表2 エゾバフンウニ変態期幼生の輸送試験結果

A Date		B*	C		D
a	b c	輸送先	所用時間		沈着率
昭和59年	4月16日	1 積丹町	a 5時間		57.6 %
60年	4月2日	2 南茅部町		b 40分	31.0
	10月22日	3 同		40	74.5
	11月21日	4 福島町	2		61.9
	12月21日	5 同	2		37.9
	d 同	6 広尾町	13		50.0
	d 同	7 伊達市	3		60.0
61年	3月18日	8 伊達市	3		30.0
	d 同	9 広尾町	13		30.3
	10月9日	10 知内町	1	30	38.5
	11月17日	11 知内町	1	30	63.4
	12月4日	12 福島町	2		32.9
	d 同	13 広尾町	13		44.2
	12月18日	14 えりも町	8	45	67.5

A. Date: a. Year (Showa 59 = 1984), b. Month, c. Date, d. same as above; B. Destination of transportation*, C. Time required: a. Hour; b. Minute; D. Settlement rate.
*Destinations: 1. Shakotan-cho, 2. Minamikayabe-cho, 3. same as above, 4. Fukushima-cho, 5. same as above, 6. Hiroo-cho, 7. Date-shi, 8. Date-shi, 9. Hiroo-cho, 10. Shiriuchi-cho, 11. Shiriuchi-cho, 12. Fukushima-cho, 13. Hiroo-cho, 14. Erimo-cho.

about 15°C which is the rearing temperature just before settlement). If the temperature lies outside this range, the settlement rate tends to diminish. If the spores of *Ulvella* growing thick on the collector are

released, the water quality deteriorates and the settlement rate decreases. The supply of water commences 2 days after the transfer.

3-6 Transportation of larvae

Experiments on the transportation of larvae at the metamorphosis stage have been carried out since 1983. The settlement rate at the beginning was about 10 %. However, due to technological improvements, the rates exceeded 30 % in 1986 and 1987 and averaged over 50 %. The transportation time was at most 13 hours and the larvae can be transported to anywhere in Hokkaido (Table 2). The method of transportation is as follows: firstly, the larvae are put into double poly bags (usually used for pickles, about 16 gallon capacity); secondly, the bags are put into a 70 L poly barrel or container; thirdly, these are closed air-tight with rubber bands and transported overland. It is desirable to have the density at the time of transportation to be about 0.8-1 individuals/cc. If the density is too high, the settlement rate decreases. The water temperature during transportation should be maintained at the set temperature. p. 7

(Kenichiro TAJIMA, Shallow Sea Department, The Culture Fishery Center)

Japanese language No. B1951

EZOBAFUNUNI JINKO SHUBYO SEISAN NO GENJO (SONO 2) (PRESENT SITUATION IN THE PRODUCTION OF ARTIFICIAL SEEDLINGS OF *Strongylocentrotus intermedius* (Part 2))

Kenichiro TAJIMA

In Part 1 in the previous issue, the "securing of parent sea urchins" and the "rearing of free-floating pluteus larvae" were introduced. In this issue, the "rearing of juvenile sea urchins in the early stages" and the "rearing of juvenile sea urchins in the late stages" are described. Herein "the juvenile sea urchins in the early stages" indicates those for which the test diameter reaches 5 mm after the time of settlement and "the juvenile sea urchins in the late stages" indicates those for which the test diameter is up to 15 mm.

4. Rearing in the early stages (Rearing on corrugated boards)

4-1 Culture of *Ulvella lens*

Ulvella lens is a species of green algae, such as *Ulva*, which multiplies in disk form. *Ulvella* is indispensable as feed for the settlement of juvenile sea urchins. Light, temperature and nutrition are essential elements in their cultivation. Therefore, it is necessary to have good lighting facilitated by transparent corrugated sheets as ceiling material. There are no problems with temperature from early summer to autumn when the air and sea water temperatures are high, but it is necessary to have some sort of heating facility in the winter and spring. Some fertilizers (nutrient salt) are added to natural sea water as a nutrient. For mass culture, the method used at the Shikabe Branch of the Culture Corporation is a simple one, described below. The

collectors are placed in a holder in the ratio of 1 collector on which *Ulvella* is well established to 4 new collectors (a 60 x 30 cm corrugated polycarbonate board). Then the nutrient salt described in Table 3 is dissolved in water and applied. When it is cultured for about 3 weeks at temperatures above 15°C without additional water, *Ulvella* propagates and becomes green. From winter to spring when the air and sea water temperatures are low, either the sea water should be heated or the entire culture room should be kept warmed. Water is changed every week during this period.

Table 3 Nutrient salt for *Ulvella lens* culture (per 1 t of sea water)

表3 ウルベラ レンズ培養のための栄養塩
（海水 1 t当り）

硝酸ナトリウム $NaNO_3$	100 g
燐酸二ナトリウム Na_2HPO_4	20 g

(Dissolved in 50 L of tap water and added)

4-2 Number of settled juvenile sea urchins

On the tenth day after settlement, the juvenile sea urchins are enumerated by taking 3-5 collectors from each of the 6 holders in the 7.5 t water tank. From past results at Shikabe-cho, when the number of juvenile sea urchins per collector is 250-300, the growth and survival rates after that date are good. If the number exceeds this range, the growth becomes uneven and sometimes the larger sea urchins eat the

smaller ones. After counting they are moved to an early stage rearing tank and the rearing process commences.

4-3 Rearing management

The test diameter of juvenile sea urchins at the time of settlement is 0.3-0.4 mm. From then on to the time when the test diameter reaches 5mm, they grow feeding on diatoms and *Ulvella* attached to the collectors. This rearing on the collectors is called rearing in the early stages. The propagation of the attached diatoms and *Ulvella* is regulated by the light, water temperature and nutrient salt. The speed of propagation varies according to the time of rearing. p. 9

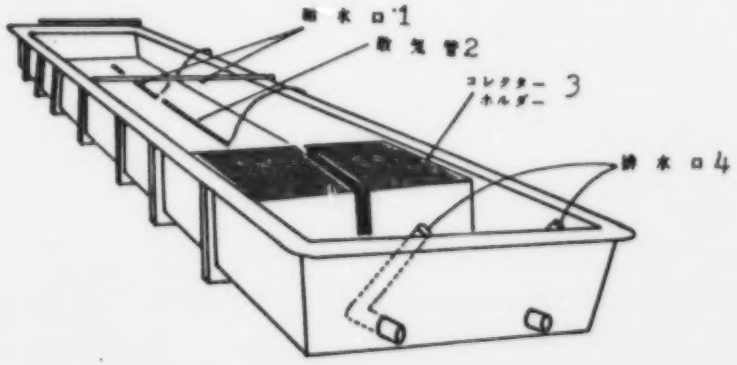

図4 エゾバフンウニ初期稚ウニ育成水槽（7.5t FRP製）

Fig. 4 Rearing water tank for juvenile sea urchins in the early stages of *Strongylocentrotus intermedius* (7.5 t FRP water tank)

1. Water supply inlet, 2. Aeration pipe, 3. Collector holder, 4. Drainage outlet.

A 7.5 t FRP water tank (Fig. 4) used for rearing abalone is usually used for the rearing tank. At the commencement of rearing the amount of water supplied is 2 t per tank per time and later increased to 4 t per tank per time. The water supply inlets are placed at 3-4

locations within the tank so that fresh sea water can be supplied as evenly as possible. In the case of rearing outdoors, the drainage outlets are placed at 2 locations on the surface of the water so that fresh water resulting from rain or snow can be drained from the surface. In winter when the air temperature becomes low or in summer when it becomes high, the air flow rate is increased so that the water temperature is not influenced by the air temperature. In particular, the sunlight is strong during summer, so the shades should be used accordingly. With regard to the collectors, many diatoms propagate in the upper part where the light is most intense. Therefore it is necessary to turn them and to remove some diatoms when there are too many attached to the collectors. When faeces of sea urchins and dead diatoms accumulate at the bottom, they should be removed with a siphon. If they are left to form a sludge, they will adversely affect the survival and growth rate of the juvenile sea urchins.

During the time from the settlement to a test diameter of 1 mm and that from 1 mm to 2 mm, the water temperature greatly affects the growth rate. For seedlings collected in autumn, the juvenile sea urchins which settle in early October, when the water temperature is high, grow to a test diameter of 5 mm by the following March, whereas those which settle in mid-December, when the water temperature is cold, grow only to about 1 mm by March.

5. Rearing in the late stages (Intermediate rearing)

5-1 Securing of seedlings for rearing in the late stages

When the test diameter of the juvenile sea urchins exceeds 5 mm, rearing on corrugated boards becomes increasingly difficult. When

the bodies of the sea urchins become large, the amount they eat exceeds the propagation rate for the diatoms on the corrugated boards and no vegetation remains on them. Then *Laminaria* and *Ulva* are put onto a corrugated holder and large-sized sea urchins are moved onto algae leaves or juvenile sea urchins are brushed off each corrugated board by hand. Juvenile sea urchins of more than 5 mm are selected using a 6-8 mm sieve. The selected juveniles are shipped for intermediate rearing. p. 10

The seedlings collected in autumn are shipped in spring-summer and those collected in spring are shipped in autumn. From spring to early autumn when the air temperature is high, close attention must be given to packing. A shallow and large styrofoam fish container without a hole in the bottom is used. A refrigerant is stuck either to the bottom or the cover, a urethane mat containing sea water is placed at the bottom, then an appropriate number of sea urchins are arranged inside so that they do not lie on top of one another. Then a urethane mat is place over them. A lid is affixed and sealed tight with gummed tape. This prevents undue increases in dryness and temperature. When this method is used, several hours of truck transportation is possible even during the middle of summer. In the case of long-distance transportation, a refrigerator truck or nighttime transportation is employed.

When 5 mm seedlings are received at a location, they are placed immediately in hanging facilities in the sea or in intermediate rearing facilities and their vitality is restored. At present the intermediate rearing of *Strongylocentrotus intermedius* is undertaken at various p. 11

Table 4 1987 results of intermediate rearing of *Strongylocentrotus intermedius*

表4 昭和62年度エゾバフンウニ中間育成結果

A 場所	B 供給数量	C 放流数量	D 生残率	E 育成様式	F 育成期間
a 天売	50,000個	40,500個	81 %	a 海中籠	201 日
b 焼尻	50,000	43,900	88	海中籠	163
c 神恵内	40,000	29,474	74	b 海中、陸上	174
d 砂古	40,000	30,000	75	a 海中籠	110
e 泊	10,000	8,115	81	c 陸上施設	167
f 寿都	40,000	14,200	36	a 海中籠	152
g 西島牧	30,000	18,905	63	海中籠	144
h 島牧	30,000	12,770	43	海中籠	152
i 瀬棚	30,000	30,400	100	海中籠	91
j 乙部	10,000	a 育成中	—	海中籠	—
k 吉岡	50,000	39,200	78	海中籠	129
l 知内	311,600	304,000	98	海中籠	110
m 上磯	86,000	69,660	—	海中籠	156
n 根崎	6,200	4,542	100	海中籠	118
o 戸井	65,000	a 育成中	—	海中籠	—
p 南茅部	189,093	60,371	32	d 海中いけす	249
q 鹿部	33,000	30,534	93	海中籠	330
r 釧路東部	50,000	a 育成中	—	e 海洋牧場	—
s 厚岸	107,995	114,504	100	a 海中籠	124
t 歯舞	20,000	a 育成中	—	海中籠	—
u 野付	36,000	a 育成中	—	e 海洋牧場	—

開始時と放流時の個数は重量から推定した

A. Location, B. Amount supplied (number of individuals), C. Amount released (number of individuals), D. Survival rate (%), E. Rearing form, F. Rearing period (days).
A: a. Teuri, b. Yagishiri, c. Kamoenai, d. Sakazuki, e. Tomari, f. Suttsu, g. Nishishimamaki, h. Shimamaki, i. Setana, j. Otobe, k. Yoshioka, l. Shiriuchi, m. Kamiiso, n. Nesaki, o. Toi, p. Minamikayabe, q. Shikabe, r. Kushiro Tobu, s. Akkeshi, t. Habomai, u. Notsuke;
C: a. Rearing in progress; E: a. Sea cage, b. Sea cage, land cage, c. Land facility, d. Sea pen, e. Ocean ranch.
* The numbers of individuals at commencement and at release were estimated from the weights.

locations in Hokkaido except for the shore areas along the Sea of Okhotsk. In 1987 the intermediate rearing experiments were carried out as a part of the experiments for the commercial production of sea urchin seedlings. The results are given in Table 4. Sea hanging facilities are used for rearing in many areas and only a few land facilities are used. Furthermore, at the Culture Fishery Center, when the technological development experiments were carried out in 1982-1984 on the mass production of sea urchin seedlings, developmental research was focused on intermediate rearing in the sea.

5-2 Sea rearing

As stated in the previous section, sea rearing is becoming the main method used in Hokkaido for rearing juvenile sea urchins in the late stages. The rearing cage used in the technological development experiments for the mass production of sea urchin seedlings is made with trical net attached to a steel frame measuring 80 x 90 x 30 cm. The cage is divided into 6 parts by partitions (Fig. 5). In the case of juvenile sea urchins of test diameter 5 mm, 5,000 individuals can be contained in this cage. When the test diameter increases to more than 10 mm, the number is reduced to less than 2,000 individuals. The mesh for juvenile sea urchins of test diameter 5-10 mm is 3mm and is 6mm for those of test diameter greater than 10 mm. If this cage is hung at a depth of about 10 m, the influences due to a sudden rise in water temperature and the passage of time can be reduced.

At present, various improvements are being made through use of cages other than those made of trical net, such as cages made of plastic

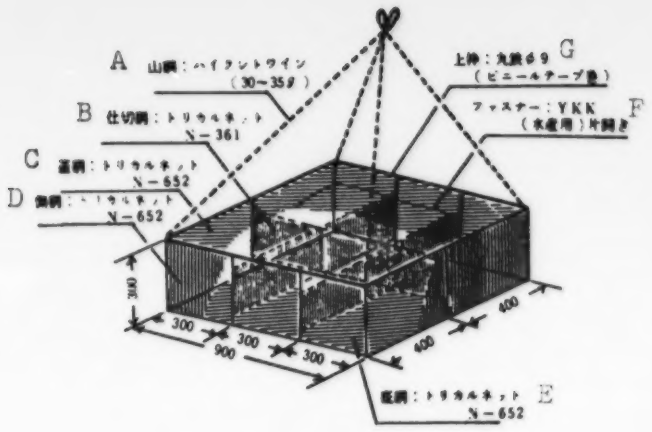

図5　エゾバフンウニ海中中間育成籠（単位mm）

Fig. 5　Cage for intermediate rearing in the sea (units mm)

A. Angle rope: hicre twine, B. Partition net: trical net, C. Cover net: trical** net, D. Side net: trical net, E. Bottom net, F. Fastener: YKK (for fishery use) one-sided opening, G. Upper frame: round steel (wound with vinyl tape)

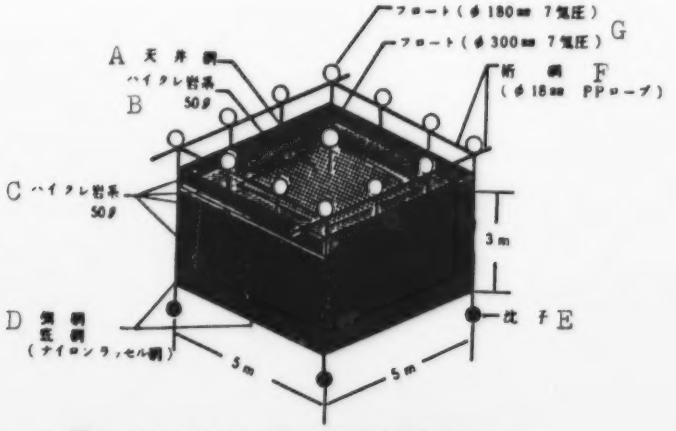

図6　エゾバフンウニ種ウニ海中中間育成用イケス
（南茅部町水産課資料より転図）

Fig. 6　Rearing pen for intermediate rearing in the sea for juvenile sea urchins of *Strongylocentrotus intermedius* (transcribed from data from the Fishery Section, Minamikayabe-cho)

A. Ceiling net, B. Hicre** twine, C. Hicre twine, D. Side and bottom nets (nylon Russell net), E. Sinker, F. Girder rope (pp rope), G. Float (air pressure 7).

which are used at Fukushima-cho for abalone culture and net pens which are used at Minamikayabe-cho (Fig.6).

Rearing management involves the supply of feed and the dispersion of juvenile sea urchins according to growth. The most important matter is that of feeding. Large-size algae, such as *Undaria* and *Laminaria* which can be got in large quantities and Itadori* *which* can be kept frozen, are used for feed. In the case of *Laminaria,* some p. 12 results show that the amount of feed taken is 0.02-0.40 g per individual per day. However, the amount of feed given should be 20-30 % greater than the amount of intake so that some feed previously given remains on the day of the next feeding. The feeding interval depends on the size of the juvenile sea urchins and on the water temperature. The intervals are twice a month for juvenile sea urchins in the early stages, 3 times a month for those in the intermediate stages and 6 times for those in the late stages. The rearing period is as follows. In the case of Funka-wan, if the rearing of juvenile sea urchins of test diameter 5 mm is commenced in April-May, they grow to a test diameter of more than 15 mm, which is the release size. In this period algae, including *Laminaria,* are plentiful and the water temperature is rising. Therefore, if they can survive the summer, the time is most suitable for intermediate rearing. November-January is the period in which feed algae such as *Laminaria* are scarce. Therefore this period is not so suitable for intermediate rearing. The feed is frozen Itadori and dried or salted *Laminaria.* The thinning of cultured *Laminaria* begins from the end of January and the feed algae becomes plentiful. Furthermore, the leaves are thin and well suited as feed for small-size juvenile sea urchins. If

rearing begins from the end of January, these juveniles will reach release size before summer.

5-3 Land rearing

Rearing of juvenile sea urchins in the late stages on land is employed in some areas. However, compared with sea rearing, there are the additional requirements of pumping facilities for the water supply and drainage and water tanks. Also there are expenses for personnel and electricity. In summer water tanks need to be cleaned often and the amount of water supplied needs to be increased.

The trical** cages (66 x 65 x 35 cm, 3 mm mesh) which are used presently for trials at the Corporation can hold about 2,000 individuals. The test diameters become greater than 15 mm in 4 months and the survival rate is about 80 %. A 7.5 t FRP water tank can hold 24-26 cages of this size. The number of seedlings produced for release is about 40,000 per tank. The amount of water supplied is 3 t per hour per tank when *Laminaria* is used as feed. Water is supplied to each cage p.13 evenly by a shower method. The amount of flow is increased in summer when the water temperature is high and shades are used to reduce the effects of the sunlight.

6. Conclusion

The culture fishery of sea urchins in various districts of Hokkaido began to develop rapidly in the Showa 60's(1985-onwards). In some areas releases of artificial and natural seedlings have been carried out. Mostly the fishery is dependent on the reproduction of natural sea urchins. The amount harvested annually in Hokkaido is about 1,300 t in weight in the shucked state. When this amount is converted to the

number of individuals, where the weight of a gonad of an individual is about 10 g, this represents about 130 million individuals. It is to be expected that in future natural sea urchin resources will continue to be utilized. However, it is important to use artificial seedlings in addition to various methods of propagation in order to maintain and increase the amount of the harvest at the present level. It is also thought that catches are maintained by transplanting of natural seedlings in a fair number of sea areas. Since the seedlings for transplantation are surely decreasing at present, it is thought that it may be possible to continue stable production in the sea urchin fishery by replacing some portion of the natural seedlings with artificial ones.

Research on the production of artificial seedlings of sea urchins began at the Culture Fishery Center in 1982. In 1987, the seedling production was commericialized at the Shikabe Branch of the Culture Fisheries Promotion Corporation. During this period, results from the Culture Centers and the Fisheries Experimental Stations of each prefecture were studied. Experiments on technological development have been carried out by incorporating the collection techniques of the artificial seedlings of Ezoawabi (*Euhaliotis discus*) developed by the Hokkaido Culture Fishery Center and the collection techniques for natural sea urchins developed by the Hokkaido Fisheries Experimental Station. At present, it is thought that the production for artificial seedlings of sea urchins is tentatively established. In future, we would like to carry on our studies and development work, aiming to reduce the cost and securing more seedlings so that they will be of use in the promotion of the culture fishery of sea urchins in Hokkaido.

(Kenichiro TAJIMA, Shallow Sea Department, The Culture Fishery Center)

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